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Other:

(54) Abstract Title: **Compression of interleaved Synthetic Aperture Radar (SAR) data**

(57) Methods and apparatus compress interleaved SAR data, comprising an In-phase (I) component and a Quadrature (Q) component. Statistical characteristics of the data are utilized to convert the data into a form that requires fewer bits in accordance with the statistical characteristics. The data may be further compressed by transforming the data and by modifying the transformed data in accordance with a quantization conversion table that is associated with the processed data. Additionally, redundancy may be removed from the processed data with an encoder. Subsequent processing of the compressed data may decompress the compressed data in order to approximate the original data by reversing the process for compressing the data with corresponding inverse operations. Interleaved I and Q components can be processed rather than separating the components before processing the data. The processed data type may be determined by providing metadata to retrieve the appropriate quantization table from a knowledge database. The quantization step may include provision for notifying the comparison module that the type of data being used cannot be identified from the metadata employed (e.g. using a feedback loop - Fig 17, not shown).

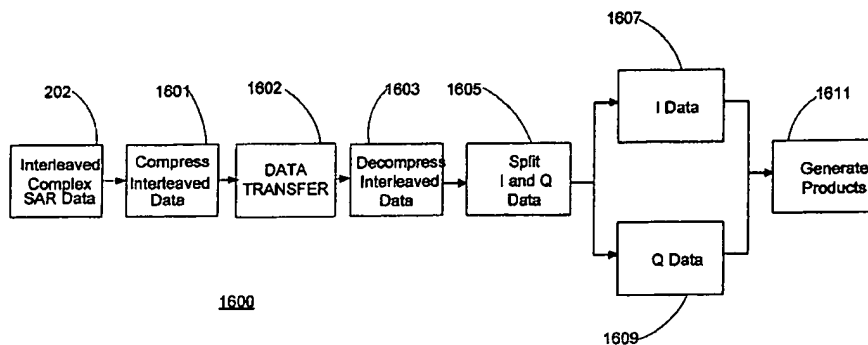


FIG. 16

31 43 05

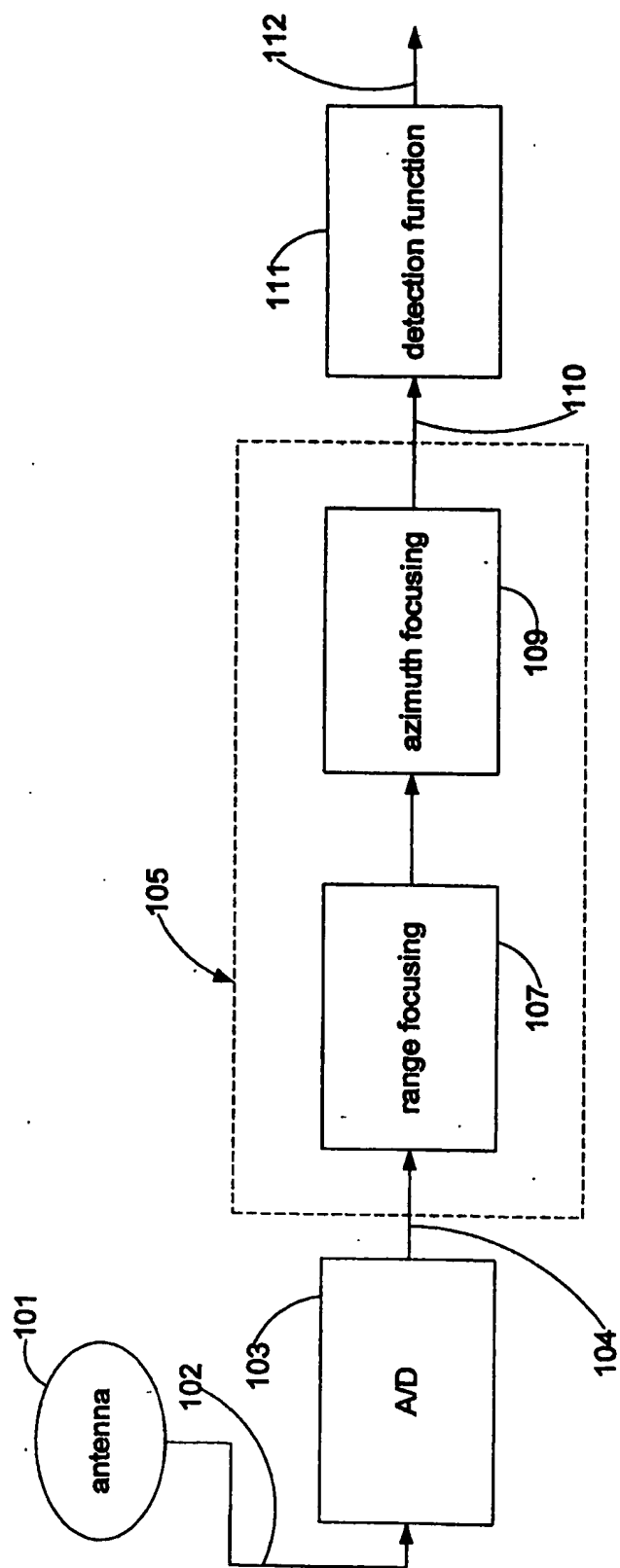


FIG. 1 (Prior Art)



**FIG. 2**

21 43 05

3/19

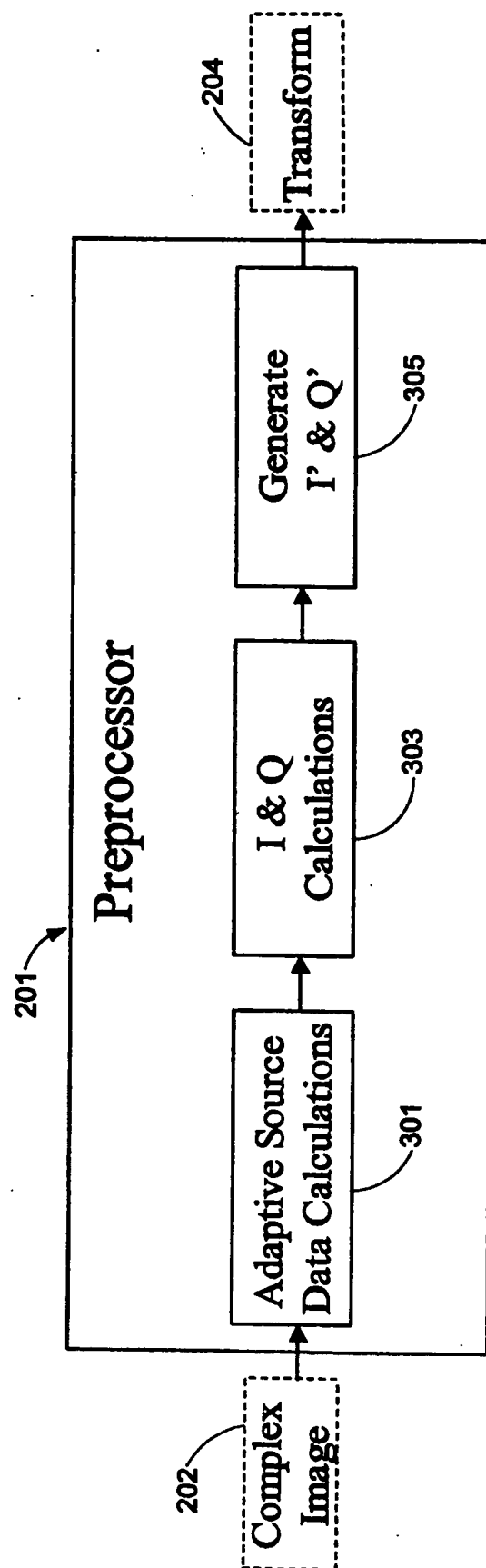


FIG. 3

01 03 05

4/19

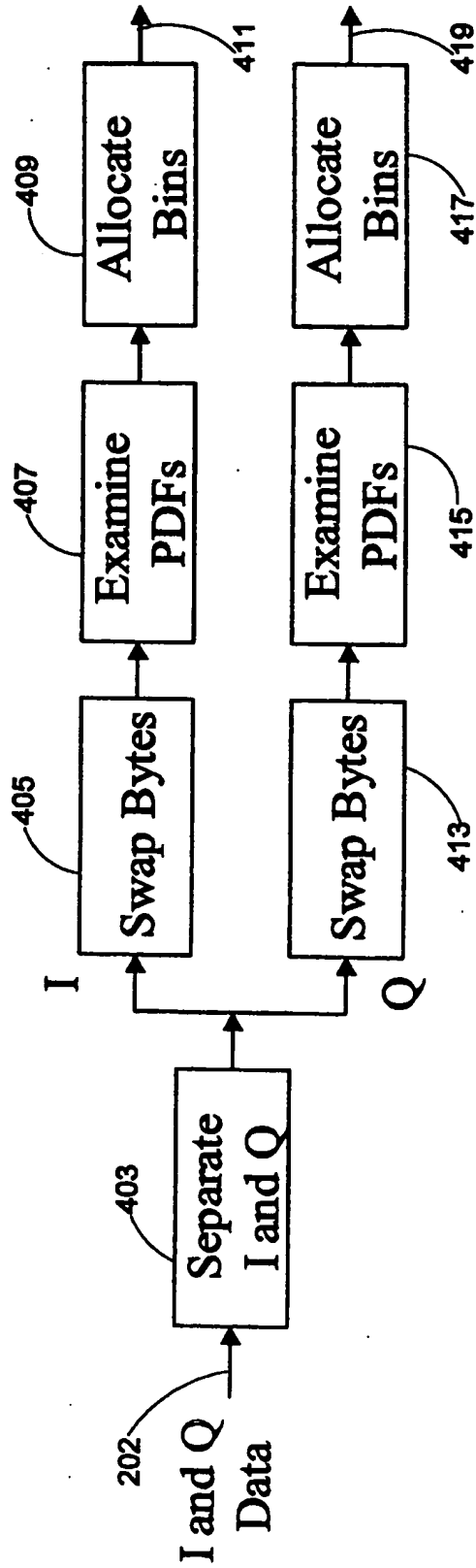


FIG. 4A

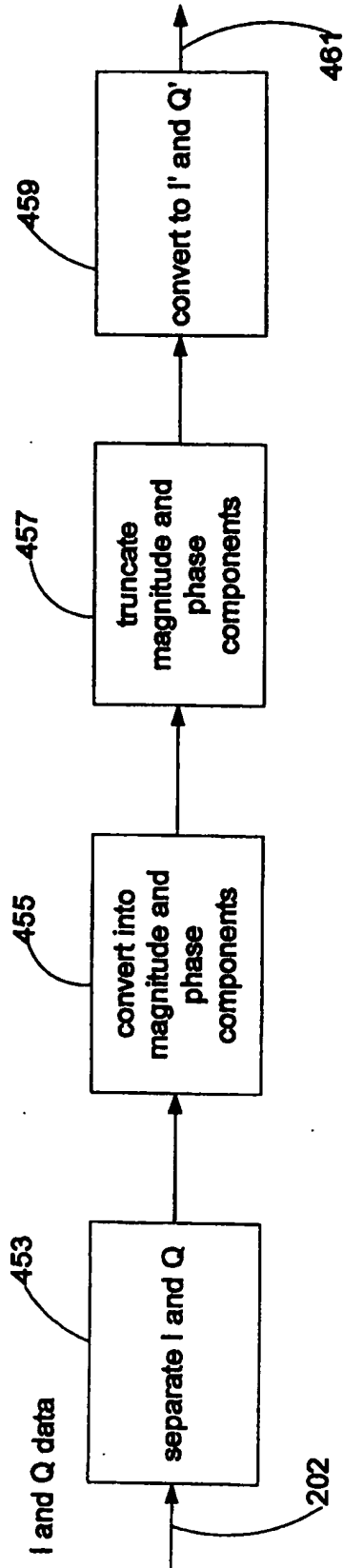


FIG. 4B



**FIG. 5**

31 03 05

7/19

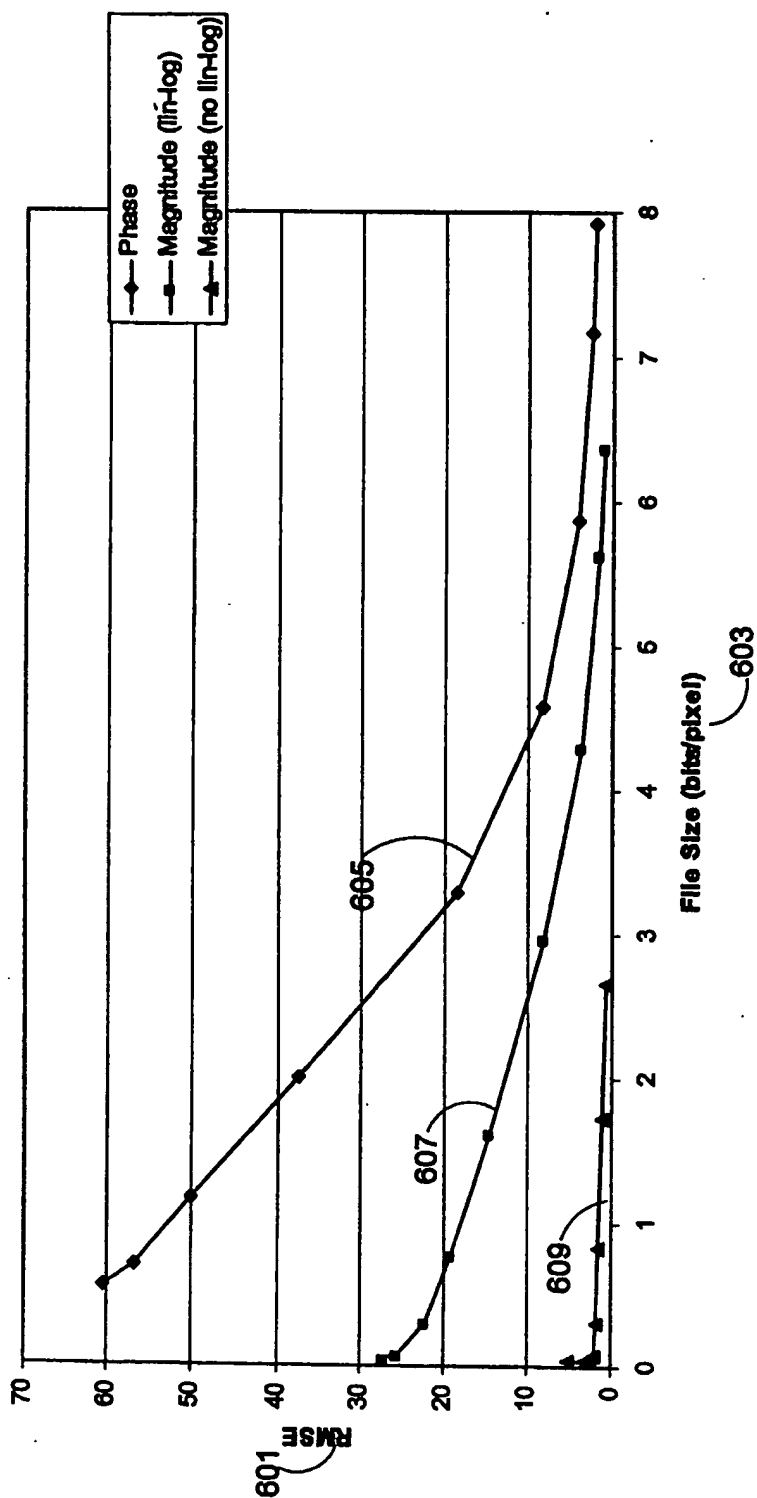


FIG. 6



21 23 25

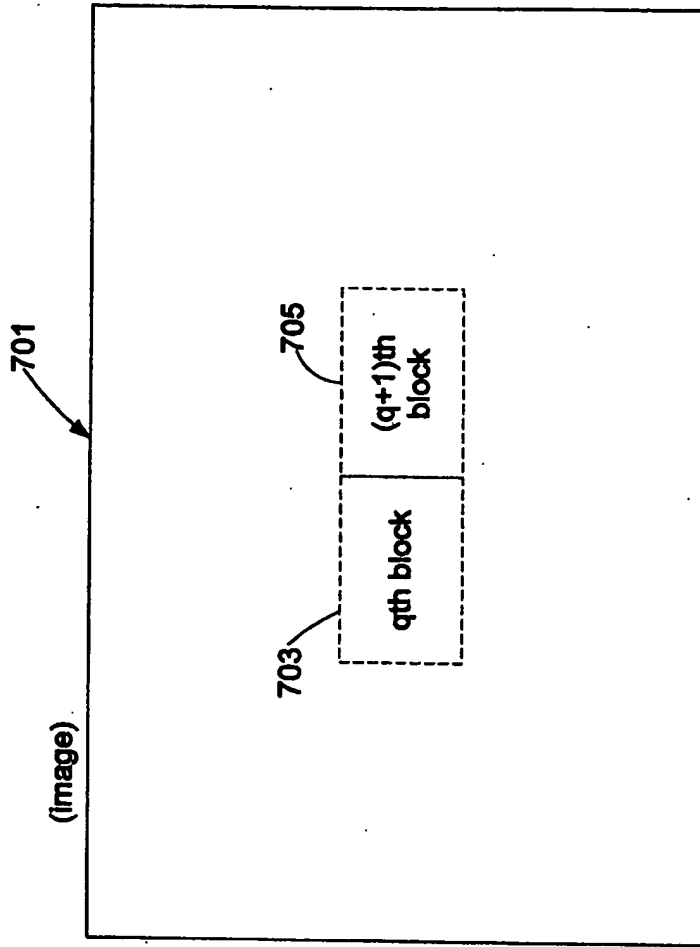


FIG. 7

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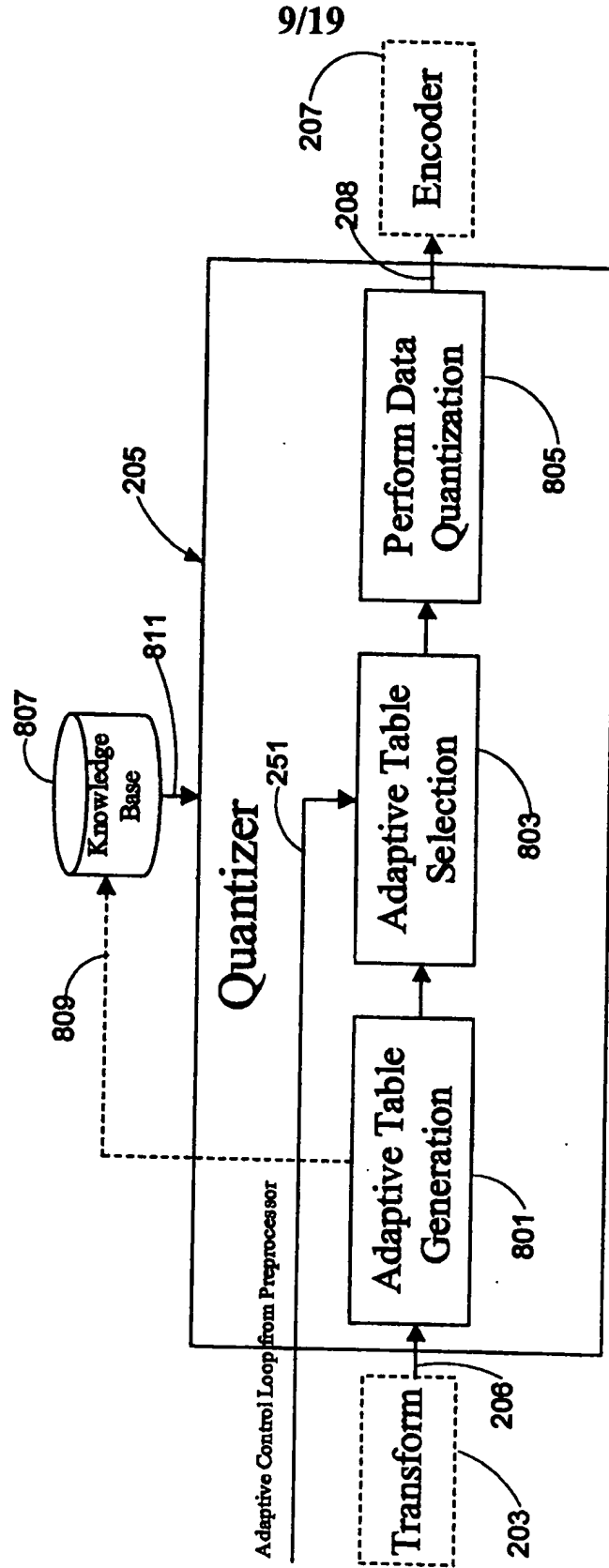


FIG. 8

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10/19

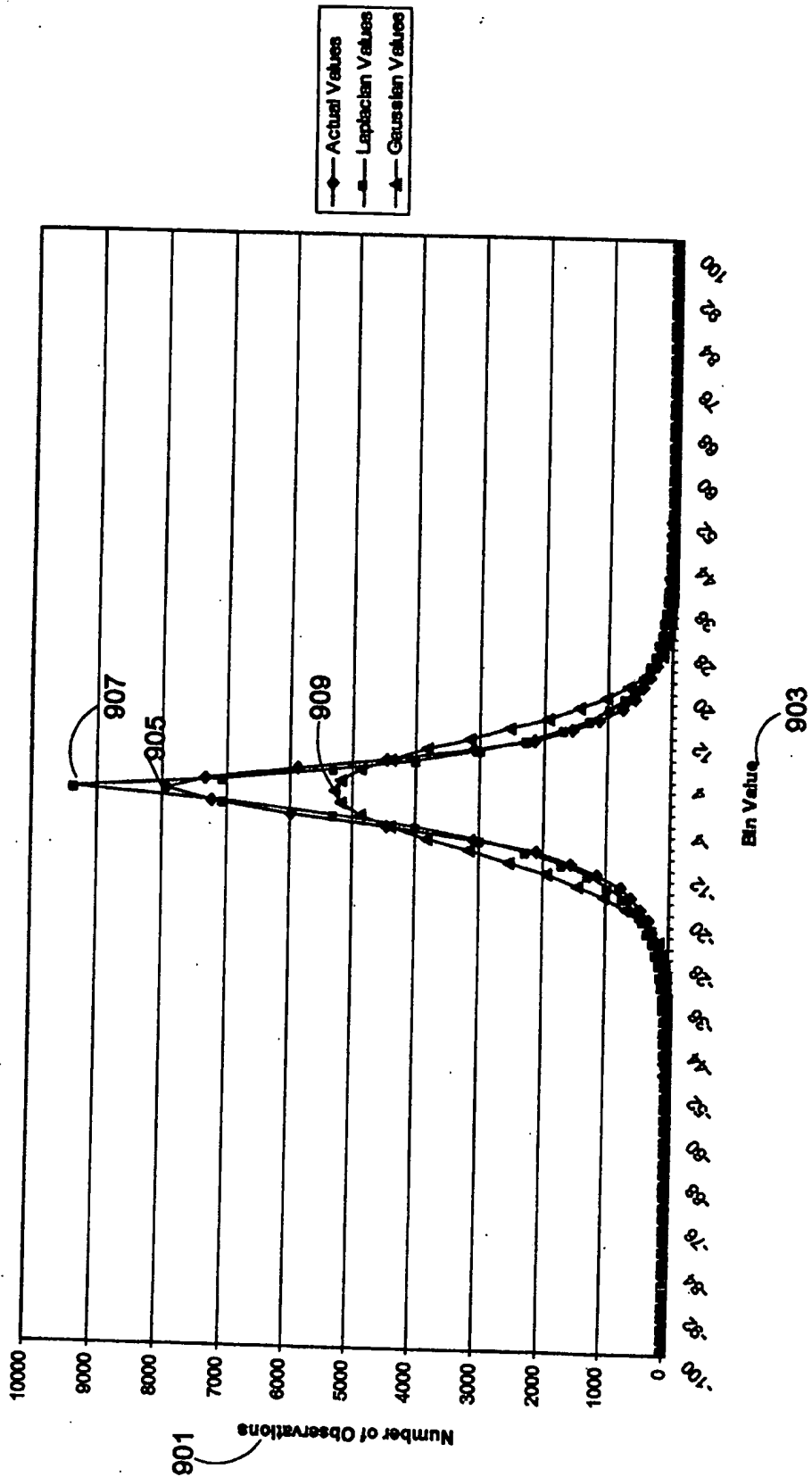


FIG. 9

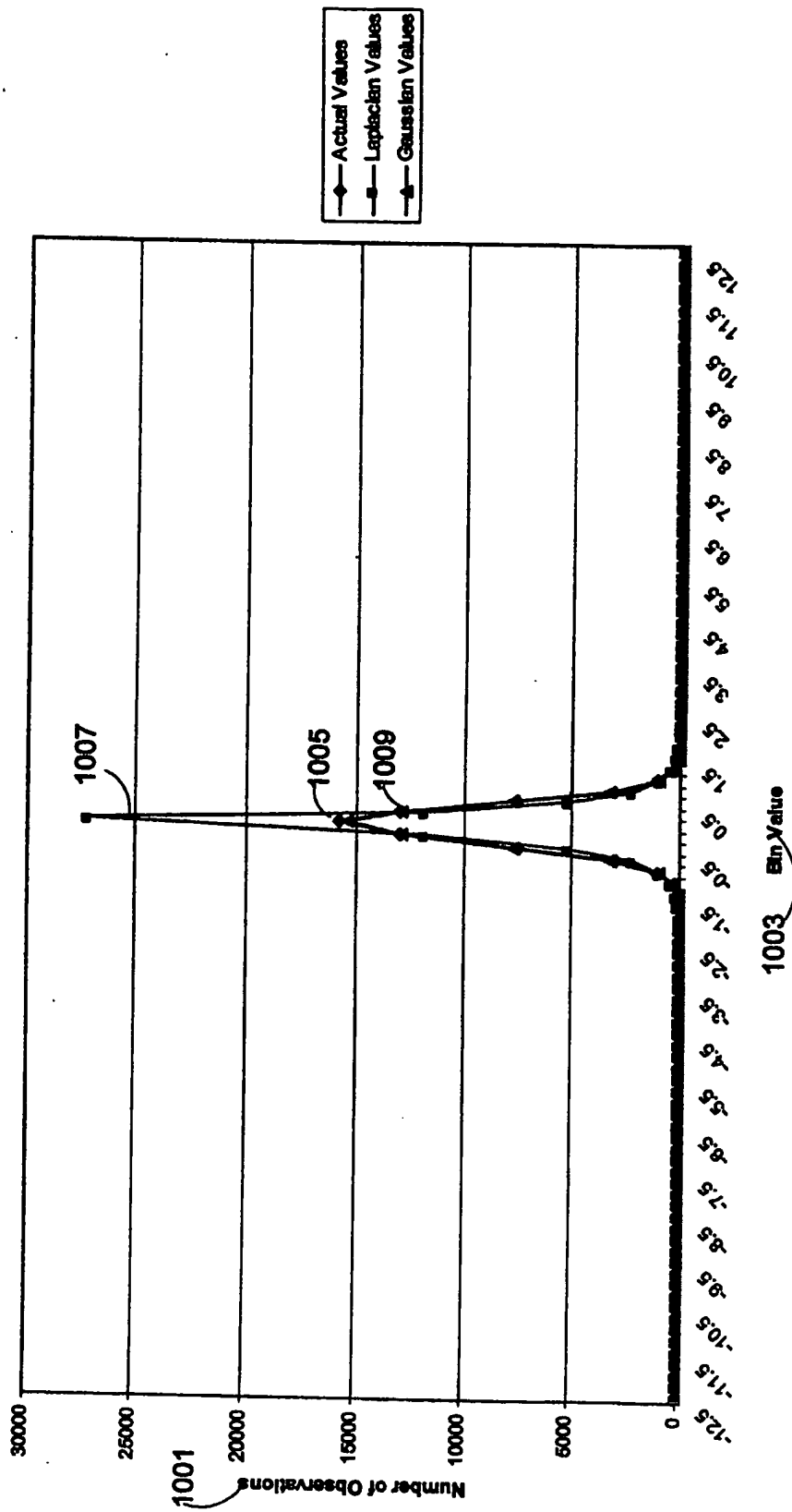
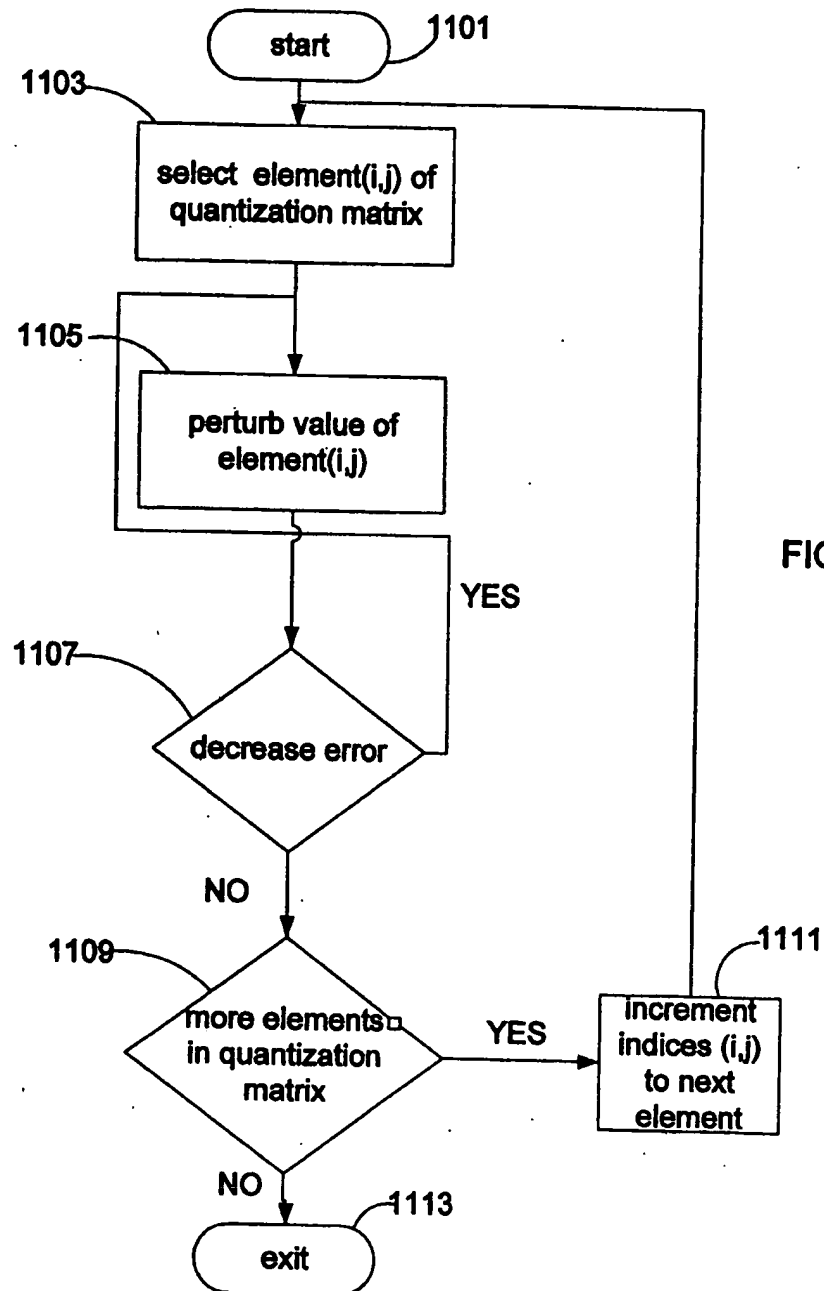


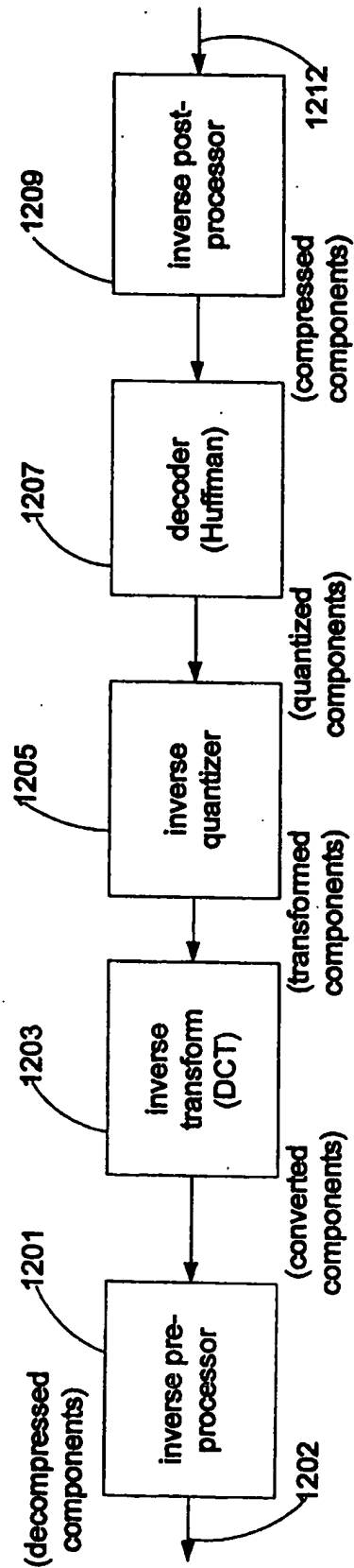
FIG. 10

1100



31 03 05

13/19



1200

FIG. 12

20130303

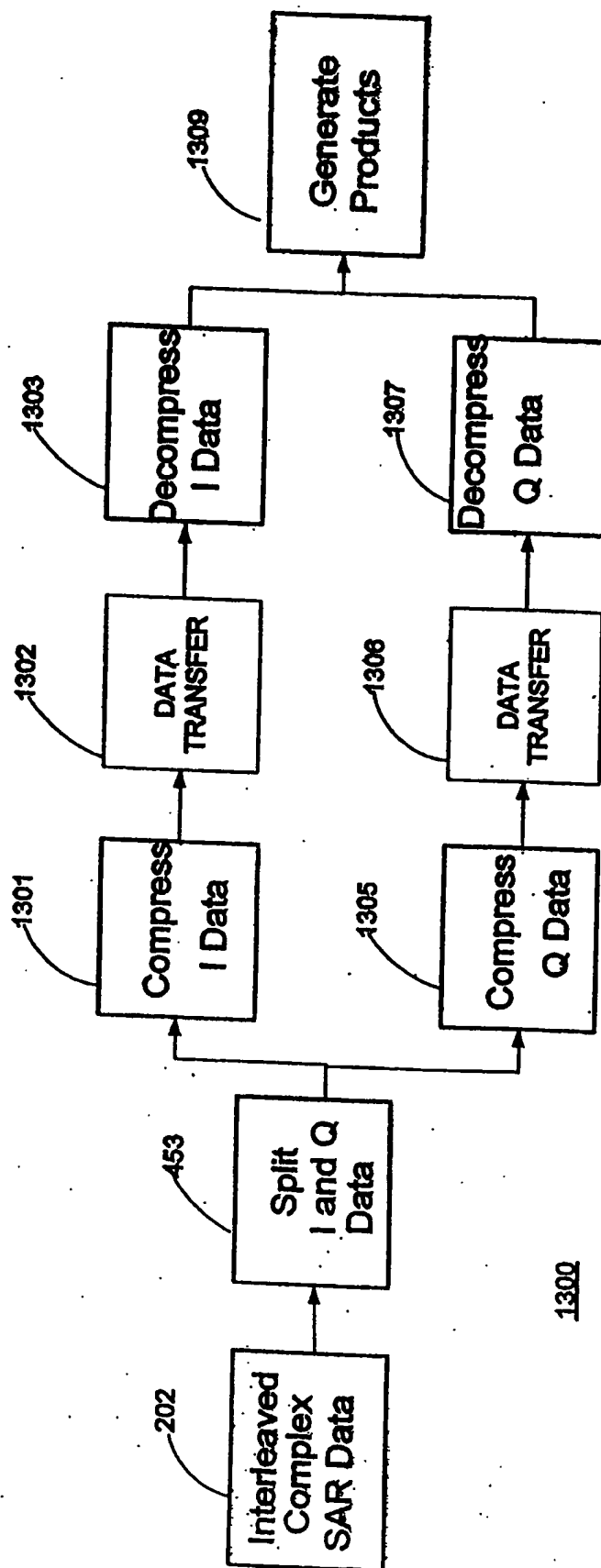


FIG. 13

21 43 03

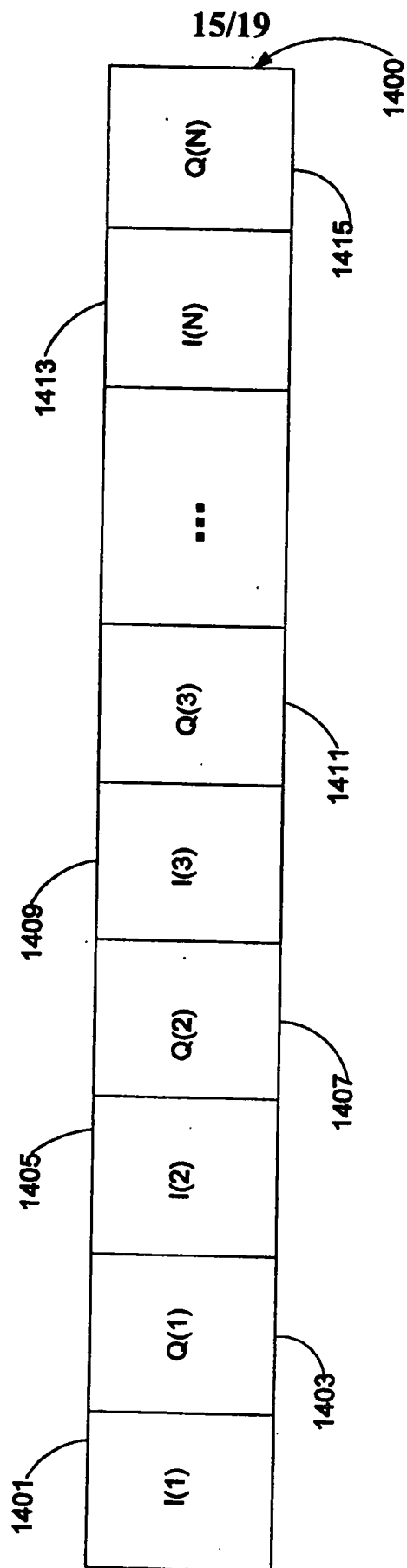


FIG. 14



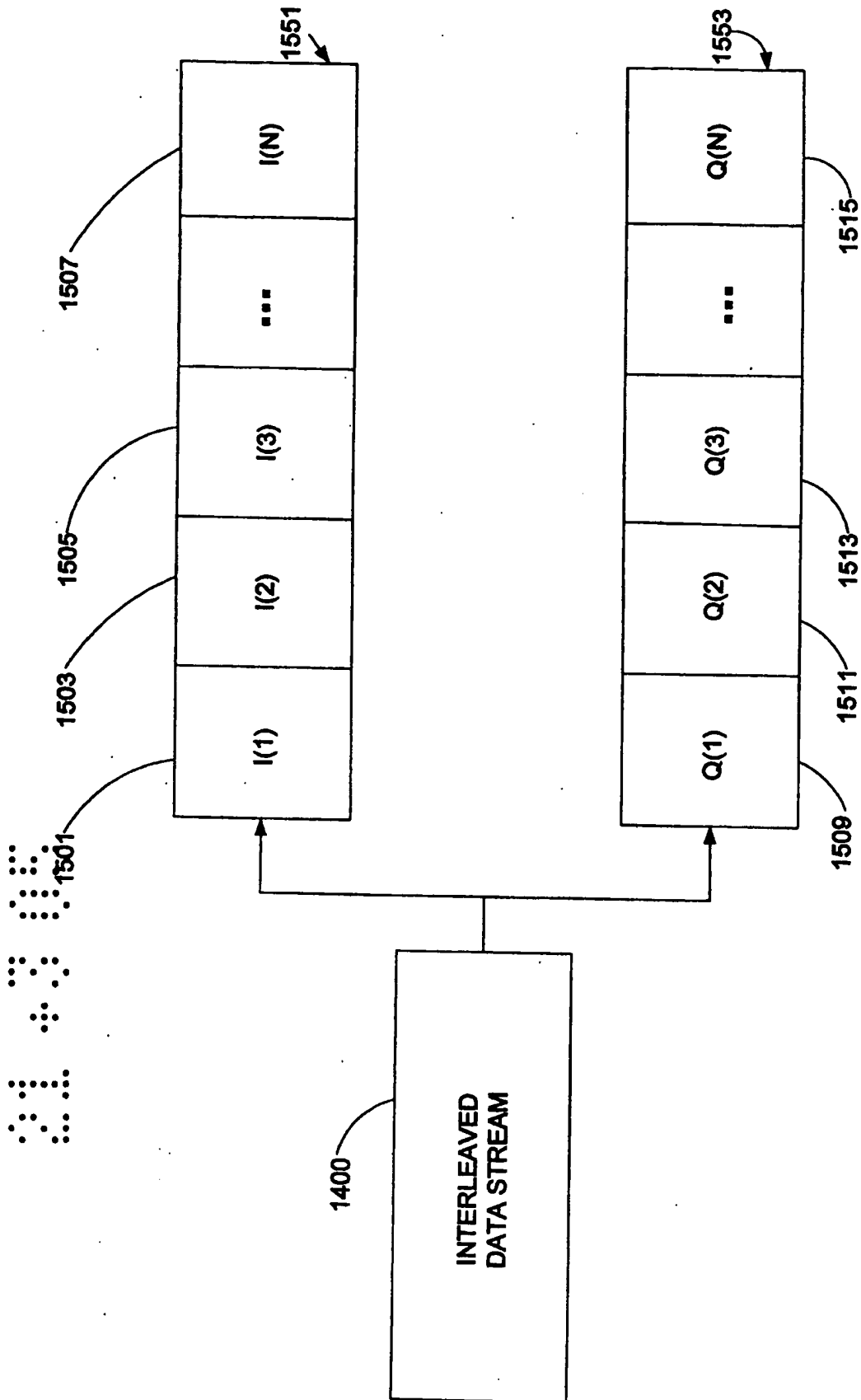


FIG. 15

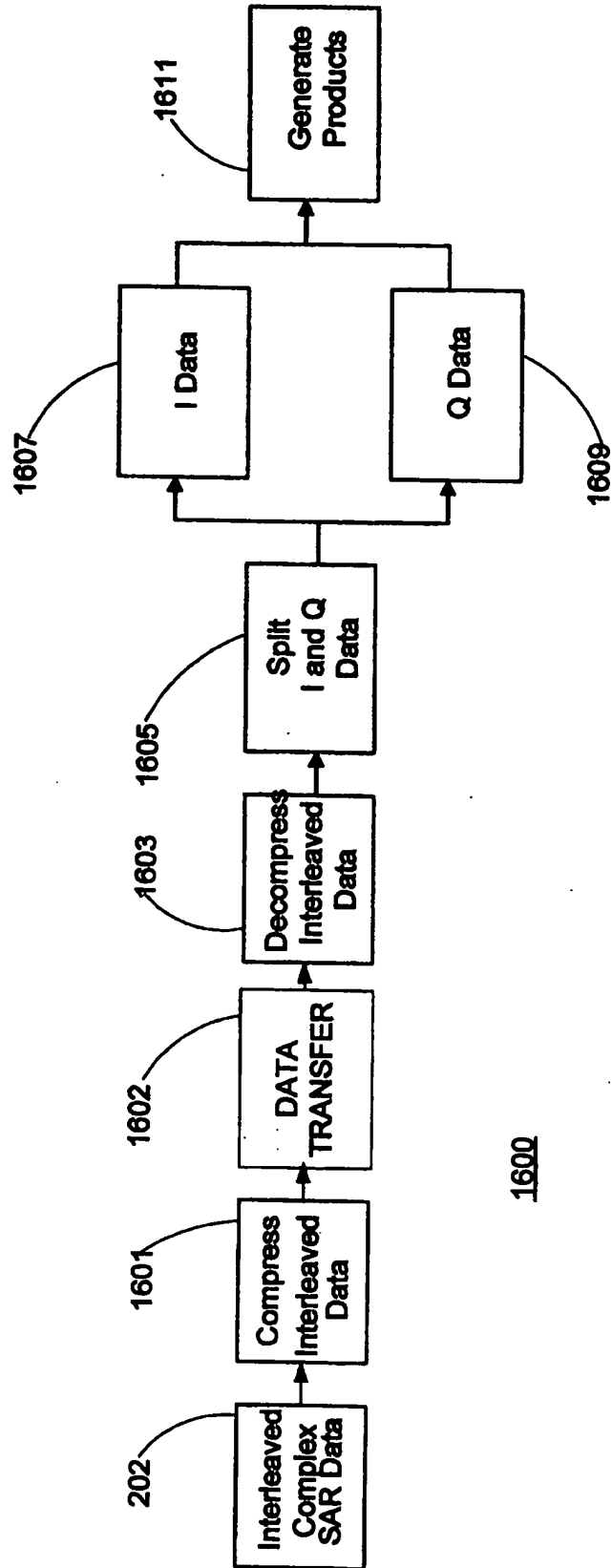


FIG. 16

202 1601 1602 1603 1605 1607 1609 1611

1600

2023.03.08

18/19

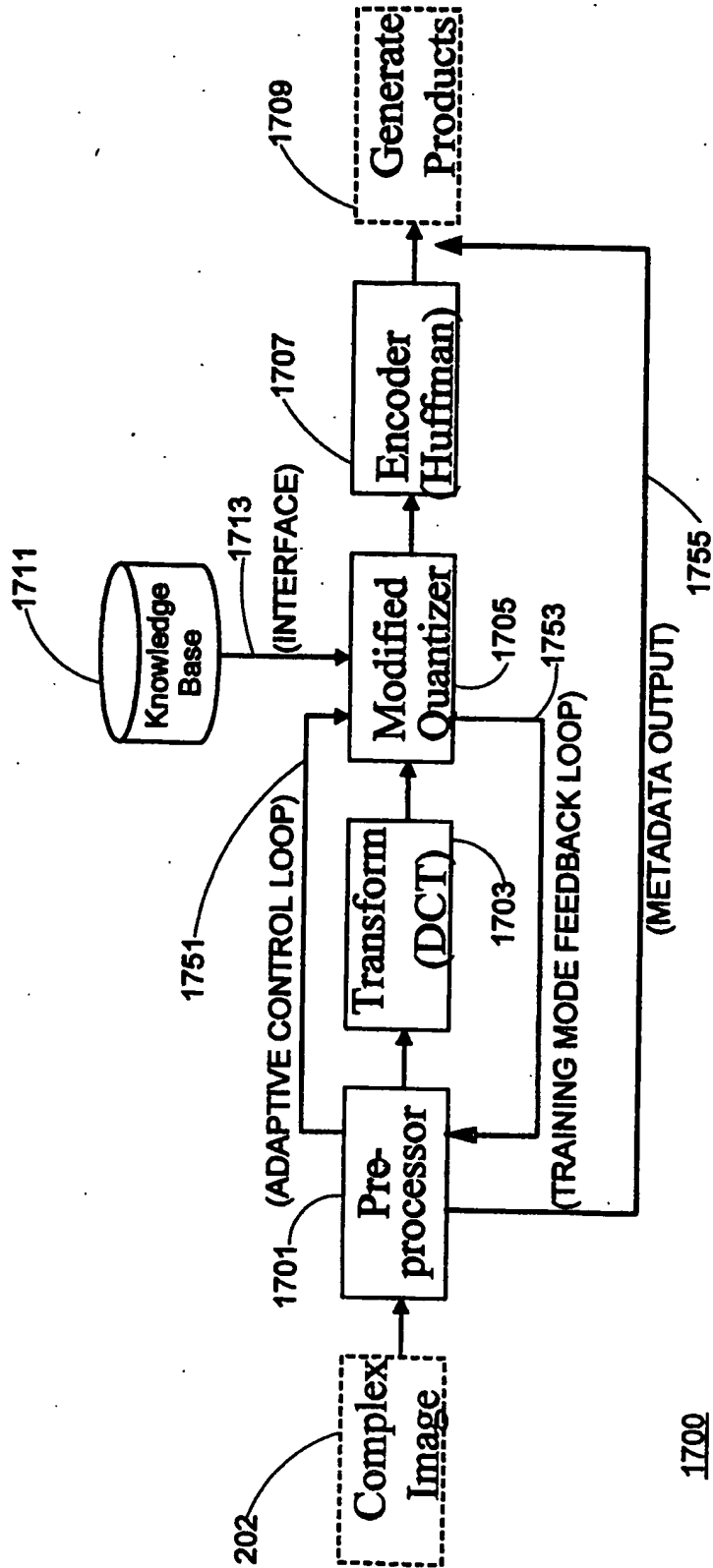


FIG. 17

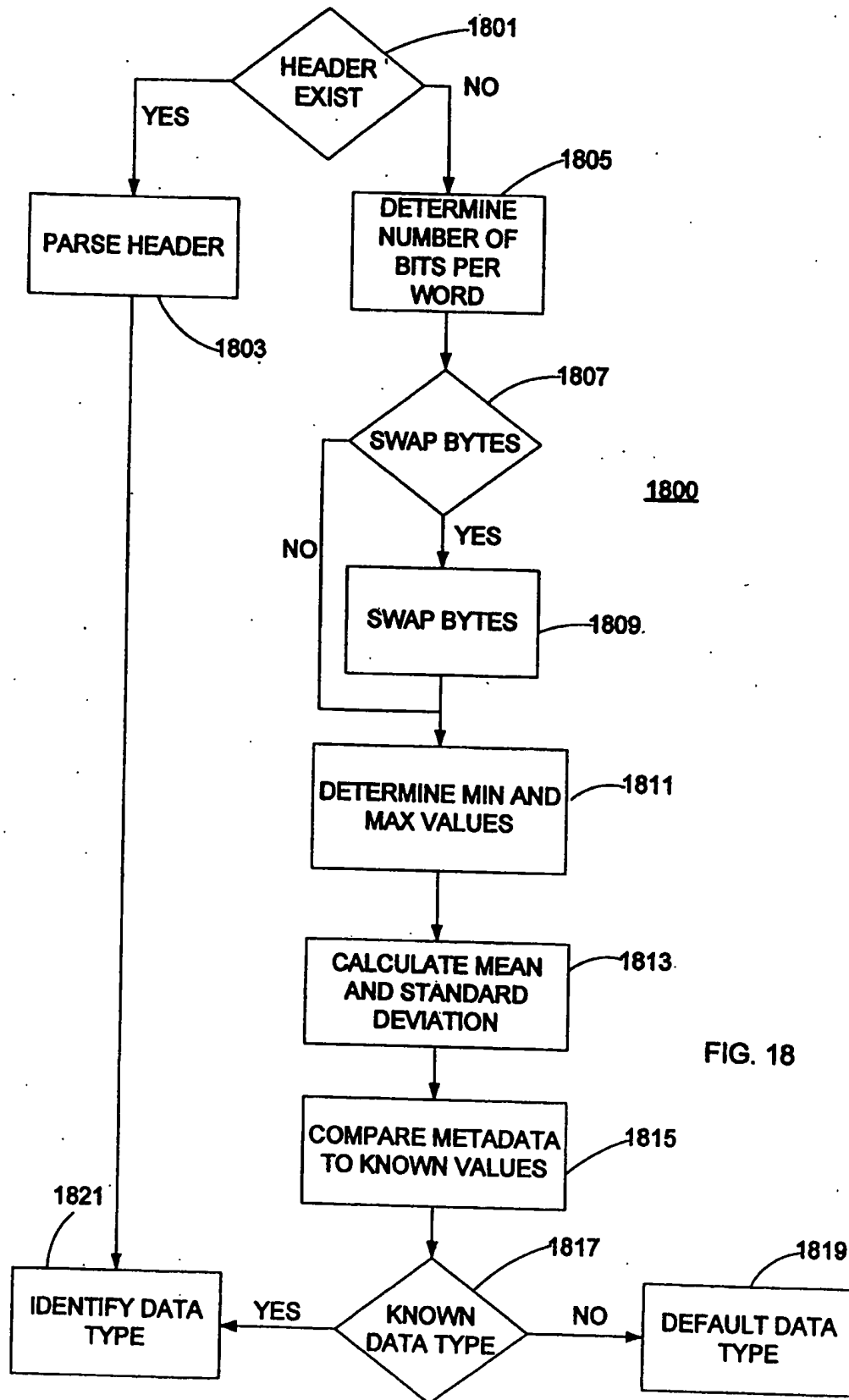


FIG. 18

**MEASUREMENT AND SIGNATURE INTELLIGENCE  
ANALYSIS AND REDUCTION TECHNIQUE**

- [01] This application is a continuation-in-part of common-owned, co-pending U.S. Application No. 10/269,818 filed on October 11, 2002, naming Francis Robert Cirillo and Paul Leonard Poehler as inventors and claiming priority to provisional U.S. Application No. 60/392,316 ("Measurement and Signature Intelligence Analysis and Reduction Technique"), filed June 28, 2002.

**Field of the Invention**

- [02] The present invention relates to compressing and decompressing data such as synthetic aperture radar data.

**Background of the Invention**

- [03] Compression of Synthetic Aperture Radar (SAR) data may require that both magnitude and phase information be preserved. Figure 1 shows data processing of synthetic aperture radar data according to prior art. Synthetic aperture radar data 102 are typically collected in analog format by an antenna 101 and is converted to digital format through an Analog-to-Digital (A/D) converter 103. The raw, unprocessed data are referred to as Video Phase History (VPH) data 104, and comprise two components: In-phase (I) and Quadrature (Q). Video phase history data 104 having multiple components, such as I and Q, are typically referred as complex SAR data. Complex SAR data are essential for the generation of complex SAR applications products such as interferograms, polarimetry, and coherent change detection, in which a plurality of such images must be processed and compared.
- [04] Video phase history data 104 are then passed through a Phase History Processor (PHP) 105 where data 104 are focused in both range (corresponding to a range focusing apparatus 107) and azimuth (corresponding to an azimuth focusing apparatus 109). The output of phase history processor 105 is referred to as Single Look Complex (SLC) data 110. A detection function 111 processes SLC data 110 to form a detected image 112.



Table 1: Popular Alternative SAR Data Compression Algorithms	
Compression Algorithm	Description
Block Adaptive Quantization (BAQ)	Choice of onboard data compression methods due to simplicity in coding and decoding hardware. Low compression ratios achieved ( $< 4:1$ ).
Vector Quantization (VQ)	Codebook created assigning a number for a sequence of pixels. Awkward implementation since considerable complexity required in codebook formulation.
Block Adaptive Vector Quantization (BAVQ)	Consists of first compressing data with BAQ and then following up with VQ. Similar to BAQ.
Karhunen-Loeve Transform (KLT)	Statistically optimal transform for providing uncorrelated coefficients; however, computational cost is large.
Fast Fourier Transform BAQ (FFT-BAQ)	2-D Fast Fourier Transform (FFT) performed on raw SAR data. Before raw data is transformed, dynamic range for each block is decreased using a BAQ.
Uniform Sampled Quantization (USQ)	Emphasizes phase accuracy of selected points.
Flexible BAQ (FBAQ)	Based on minimizing mean square error between original and reconstructed data.
Trellis-Coded Quantization (TCQ)	Unique quantizer optimization design. Techniques provide superior signal to noise ratio (SNR) performance to BAQ and VQ for SAR.
Block Adaptive Scalar Quantization (BSAQ)	BSAQ's adaptive technique provides some performance improvement.

- [07] Existing optical algorithms are inadequate for compressing complex multi-dimensional data, such as SAR data compression. For example with optical imagery, because of a human eyesight's natural high frequency roll-off, the high frequencies play a less important role than low frequencies. Also, optical imagery has high local correlation and the magnitude component is typically more important than the phase component. However, such characteristics may not be applicable to complex multi-dimensional data. Consequently, a method and apparatus that provides a large degree of compression without a significant degradation of the processed signal are beneficial in advancing the





- [10] Variations of the embodiment may use a subset of the apparatus modules of the first or the second embodiment. In a variation of the embodiment, the apparatus comprises a preprocessor, a transform module, and a quantizer.
- [11] With another embodiment of the invention, interleaved I and Q components of SAR data can be processed rather than separating the components before processing the data. Thus, one is not constrained to separately compress and decompress the I and Q data. With the processing of interleaved I and Q data, one may assume that the statistical characteristics are the same, in which a deviation from this assumption may result in a reduced compression ratio. Moreover, the processing of interleaved data is applicable to data that are characterized by one or more dimensions.
- [12] With another embodiment of the invention, the data type being processed for compression and decompression is determined. With the compression process, the preprocessor interacts with the quantizer. The preprocessor provides metadata to the quantizer so that the quantizer can retrieve the appropriate quantization table from a knowledge database. The metadata may include statistical characteristics of the data being processed such as the mean, the standard deviation, and the maximum/minimum values. This aspect of the invention also supports a training mode, in which the quantizer informs the preprocessor so that a new data type can be specified.

#### **Brief Description of the Drawings**

- [13] A more complete understanding of the present invention and the advantages thereof may be acquired by referring to the following description in consideration of the accompanying drawings, in which like reference numbers indicate like features and wherein:
- [14] Figure 1 shows data processing of synthetic aperture radar data according to prior art;
- [15] Figure 2 shows an apparatus for compressing data in accordance with an embodiment of the invention;

- [16] Figure 3 shows a preprocessor apparatus for preprocessing a complex image in accordance with an embodiment of the invention;
- [17] Figure 4A shows a process for binning data associated with a complex image in accordance with an embodiment of the invention;
- [18] Figure 4B shows a process for truncating magnitude and phase components of a complex image in accordance with an embodiment of the invention;
- [19] Figure 5 shows probability density functions that are associated with In-phase (I) and Quadrature (Q) components of exemplary synthetic aperture radar (SAR) data;
- [20] Figure 6 shows Root Mean Square Error (RMSE) values that are associated with magnitude and phase data for processed signal data as shown in Figure 2 in accordance with an embodiment of the invention;
- [21] Figure 7 shows a partitioning of complex image data in order to obtain Discrete Cosine Transform (DCT) in accordance with an embodiment of the invention;
- [22] Figure 8 shows an apparatus for quantizing Discrete Cosine Transform (DCT) data in accordance with an embodiment of the invention;
- [23] Figure 9 shows a representative histogram for a low order Discrete Cosine Transform (DCT) coefficient in accordance with an embodiment of the invention;
- [24] Figure 10 shows a representative histogram for a high order Discrete Cosine Transform (DCT) coefficient in accordance with an embodiment of the invention;
- [25] Figure 11 shows a heuristic process for determining a quantization matrix according to an embodiment of the invention;
- [26] Figure 12 shows an apparatus for decompressing data in accordance with an embodiment of the invention;



better compression results than with VPH data 104, but SLC 110 data are only available after processing has occurred.

- [35] Other embodiments of the invention may support other applications of complex multidimensional data, including weather data, oil and gas exploration data, encrypted/decrypted data, medical archival of MRI/CTI and three dimensional sonograms, digital video signals, and modem applications.
- [36] Referring again to Figure 2, apparatus 200 comprises a preprocessor 201, a transform module 203, a quantizer 205, an encoder 207, and a post-processor 209 in order to provide compressed data 212. SAR data 202 may comprise SAR pixel data that may be provided in the form of two floating-point numbers representing In-phase (I) and Quadrature (Q) components. (SAR data 202 may be considered as being "received" even though the data may not be received from a radio receiver but obtained from a memory that stores the data.) Preprocessor 201 may convert the I and Q components to Magnitude (M) and Phase ( $\phi$ ) components in accordance with a second embodiment as will be discussed in the context of Figure 4B. Additionally, preprocessor 201 may convert the I and Q components into magnitude and phase components to facilitate viewing SAR data 202. The magnitude and the phase components may be obtained from the in-phase and quadrature components by using Equations 1 and 2.

$$M = (I^2 + Q^2)^{1/2} \quad (\text{EQ. 1})$$

$$\phi = \tan^{-1} (Q / I) \quad (\text{EQ. 2})$$

Moreover, I and Q components may be obtained from the magnitude and the phase components by using Equations 3 and 4.

$$I = M \cos \phi \quad (\text{EQ. 3})$$

$$Q = M \sin \phi \quad (\text{EQ. 4})$$

Additionally, the power of a SAR signal may provide good visual results when printing intensity (magnitude-only) imagery. The power of a SAR signal may be obtained from Equation 5.

$$P = 20 \log_{10} M^2 \quad (\text{EQ. 5})$$

- [37] The conversion between  $(I, Q)$  and  $(M, \phi)$  as expressed in EQs. 1-4 allows SAR data 202 to be studied in both data formats before and after compression. When SAR data 202 are represented as magnitude and phase components, additional bits may be allocated to the phase component versus the magnitude component to achieve the least degradation of the phase product, depending on characteristics of SAR data 202. In an embodiment, more bits (e.g. six bits) of the phase component and fewer bits (e.g. two bits) of the magnitude component are used to generate compressed I and Q components. Conversely, when SAR data 202 are represented by in-phase and quadrature components, apparatus 200 can process the in-phase component separately from the quadrature component for a single complex image.
- [38] Preprocessor 201 also determines a data type (as discussed in the context of Figure 3) and informs quantizer 205 through an adaptive control loop 251.
- [39] Figure 3 shows preprocessor apparatus 201 (as shown in Figure 2) for preprocessing complex image 202 in accordance with an embodiment of the invention. Preprocessor apparatus 201 reduces the number of bits that are needed to represent complex data  $(I, Q)$  within a specified degradation (corresponding to an error metric). Typically, VPH data 104 or SLC 110 data are represented by  $(I, Q)$  data pairs 202, in which each pair uses 64, 32, or 16 bits, and where I and Q are separately represented in 32, 16, or 8-bit formats, respectively. Data 202 may be formatted in which an ordering of the most significant to the least significant bytes may be reversed with respect to the assumed order that preprocessor 201 processes data 202. In such a case, preprocessor 201 may perform "byte swapping" to reorder data 202 in accordance with the assumed ordering of the constituent bytes.
- [40] An adaptive source data calculations module 301 separately processes the I and Q components of  $(I, Q)$  data pairs 202 in order to determine corresponding statistical characteristics. (An example of statistical characteristics is shown in Figure 5, in which the I component has approximately the same statistical characteristics as the Q component.) In the embodiment, a general-purpose computer (e.g. an associated

microprocessor) measures the number of occurrences of the I component or the Q component as a function of the value of the I component or the Q component. Additionally, adaptive source data calculations module 301 performs header analysis by reading information provided at the beginning of a data file comprising data 202 in order to determine the format of the data being analyzed, e.g. the number of bits that are associated with (I,Q) data 202. Module 301 also performs data analysis that provides statistical characteristics of data 202 as may be characterized by probability density functions of the I component and the Q component (as exemplified by Figure 5). Module 301 determines a bin assignment that may vary with the value of the I or Q component. In the embodiment, a size of a bin is inversely related to a value of the probability density function at a midpoint of the bin. A calculations module 303 uses the statistical characteristics of data 202 to assign the I and Q components into bins. A module 305 uses the bin identity to form the I' and Q' components (converted I component and converted Q component, corresponding to data 204 in Figure 2), having 8-bit integer values between 0 and 255 by efficiently allocating bins, in which most of the bins are assigned to a range containing the most data points. For example, data (corresponding to either I or Q) may range from -10,000 to +10,000 units, in which over 99.9% of the data are contained within a range of -2,000 to +2,000 units. In such a case, most of the bins would be allocated between the smaller range (i.e. -2000 to +2,000 units) rather than the larger range (i.e. -10,000 to +10,000 units).

- [41] In a variation of the embodiment, Single Look Complex (SLC) data 110 are transformed using a Fast Fourier Transform (FFT) prior to binning data 202 by modules 303 and 305, wherein a transformation of SLC data 110 has statistical characteristics that are similar to VPH data 104. (In the embodiment, modules 303 and 305 bin data 202 by first processing the I component and subsequently processing the Q component.) However, other embodiments of the invention may utilize other transform types in order to modify statistical characteristics of the data. After quantization by modules 303 and 305, the transformed SLC data are inversely transformed using an Inverse Fast Fourier Transform (IFFT).

[42] Figure 4A shows a process for binning data associated with complex image data 202, as performed by module 303 in accordance with an embodiment of the invention. Complex image data 202 are separated into I and Q components by a module 403. If the most to the least significant bytes need to be reordered, modules 405 and 413 swap bytes for the I component and Q component, respectively. Modules 407 and 415 determine the probability density functions for the I component and the Q component, respectively over data files (comprising static images of a data gathering session). As discussed in the context of Figure 5, the probability density functions of the I component and the Q component may be essentially the same so that embodiments of the invention may utilize one module by separately processing the I and Q components. Modules 409 and 417 bin the I component and the Q component, respectively. The greater the probability density function  $p(x_i)$ , where  $x_i$  is the center value of the  $i^{\text{th}}$  bin, the smaller the range of the  $i^{\text{th}}$  bin in order to provide better resolution for data within the  $i^{\text{th}}$  bin.

[43] Figure 4B shows a process for truncating magnitude and phase components of a complex image in accordance with a second embodiment of the invention. In a second embodiment of the invention, module 305 of preprocessor apparatus 201 may utilize a different number of bits that are associated with the phase component ( $\phi$ ) than is associated with the magnitude component ( $M$ ). In the embodiment, fewer bits from the magnitude component (a truncation of  $M$ ) and more bits from the phase component (a truncation of  $\phi$ ), as determined from Equations 1 and 2 by converting I and Q into  $M$  and  $\phi$ , are used to generate compressed components  $I'$  and  $Q'$ , as determined from Equations 3 and 4 by converting the truncations of  $M$  and  $\phi$  into  $I'$  and  $Q'$ . Allocating more bits from the phase component helps preserve phase information, as may be the case with Video Phase History (VPH) data 104. As shown in Figure 4B, complex image data 202 is separated into I and Q components by module 453. The I and Q components are converted into magnitude and phase components by module 455. Module 457 truncates the magnitude and phase components in order to retain a desired number of bits from each of the components. Module 459 converts the truncated portions of the magnitude and phase components to form compressed components  $I'$  and  $Q'$  (corresponding to data 461).





- [46] Figure 6 shows Root Mean Square Error (RMSE) values that are associated with magnitude and phase data for processed data (e.g. processed SAR data 204) as shown in Figure 2 in accordance with an embodiment of the invention. (The root mean square error is a measure of the quantization error by relating the compressed data with the original data.) Values 601 are related to an assigned number of bits per pixel 603 for phase data 605, magnitude data 607 (with a linear-log representation), and magnitude data 609 (no linear-log representation). Similarly, calculations may be performed for (I, Q) data. Root mean square error and Peak Signal to Noise Ratio (PSNR) figures of merit may be initially used as a basis for designing preprocessor 201 and for the evaluating the compressed imagery.
- [47] Processed SAR data 204 (comprising a converted I component and a converted Q component) are further processed through transform module 203 using a Discrete Cosine Transform (DCT) in order to obtain the frequency representation of the in-phase and the quadrature data as transformed data 206 (comprising a transformed I component and a transformed Q component). As will be discussed in the context of Figure 7, the converted I component and the converted Q component of SAR data 204 are separately partitioned into smaller blocks. (Each block is essentially independent of other blocks so that each block may be processed individually in order to process an entire image.) The discrete cosine transform is well known in the art, and is given by Equation 6.

$$B(k_1, k_2) = \sum_{i=0}^{N_1-1} \sum_{j=0}^{N_2-1} 4 \cdot A(i, j) \cdot \cos \left[ \frac{\pi \cdot k_1}{2 \cdot N_1} (2 \cdot i + 1) \right] \cdot \cos \left[ \frac{\pi \cdot k_2}{2 \cdot N_2} (2 \cdot j + 1) \right] \quad (\text{EQ. 6})$$

In Equation 6, pair (i,j) represents a pixel of processed SAR data 204 within a block (which is a portion, A(i,j) represents a corresponding in-phase or quadrature value of the pixel, and B(k<sub>1</sub>,k<sub>2</sub>) represents a corresponding DCT coefficient, where pair (k<sub>1</sub>,k<sub>2</sub>) identifies the DCT coefficient in the DCT matrix. In the embodiment, a DCT coefficient is calculated over an eight by eight pixel block, i.e. N<sub>1</sub> and N<sub>2</sub> equal 8, although other embodiments of the invention may use a different value for N. (The collection of DCT coefficients may be represented by an 8 by 8 matrix.)



providing quantized DCT data 208 (comprising a quantized I transform or a quantized Q transform). Each element of the quantization matrix is determined by statistics for the corresponding DCT coefficient in accordance with a specified maximum error (e.g. a root mean square error, a peak signal to noise ratio, and a byte by byte file comparison). (Figures 9 and 10 show statistics for the (1,1) and the (7,7) DCT coefficients, respectively.) The larger the value of an element of the quantization matrix, the greater the corresponding step size (with less resolution). However, dividing an element of the DCT matrix by a larger number reduces the quantized value. If the quantized value is sufficiently reduced, the resulting value may be considered as being zero by encoder 207 if a specified maximum error (e.g. the root mean square error) is satisfied.

- [51] In a variation of the embodiment, the quantization matrix may be determined by reducing a Measurement and Signature Intelligence (MASINT) product distortion. (In some cases, the reduction may correspond to a minimization of the distortion.) The distortion may be determined from interferometric SAR, coherent change detection (CCD), and polarimetry products. Interferometric SAR (IFSAR) is a comparison of two or more coherent SAR images collected at slightly different geometries. The process extracts phase differences caused by changes in elevation within the scene. IFSAR produces digital terrain elevation data suitable for use in providing terrain visualization products. (Products are generally referred as Digital Elevation Models (DEM).) These products are used in mapping and terrain visualization products. The advantage of IFSAR height determination is that is much more accurate than other methods, such as photo/radargrammetry methods that use only the intensity (magnitude) data, because phase is used and height determination is done with wavelength measurements which are very accurate (i.e. for commercial systems at C Band (5 GHz) approximately 5.3 cm)).
- [52] Coherent Change Detection (CCD) is a technique involving the collection and comparison of a registered pair of coherent SAR images from approximately the same geometry collected at two different times (before and after an event). The phase information, not the magnitude, is used to determine what has changed between the first

and second collection. This can determine scene changes to the order of a wavelength (5.3 cm) and may denote ground changes/activity occurring between collections.

- [53] Polarimetry products are generally collected using systems that can independently radiate and collect vertical and horizontal complex SAR data. This technique is accomplished by alternately radiating vertical and horizontally polarized SAR pulses, receiving on both horizontal and vertical antennas, and saving the complex data from each. The product formed is a unique target signature for objects with an associated complex polarized radar reflectance. This technique is used in many automatic target recognition systems (ATR).
- [54] In a variation of the embodiment, each member of the quantization matrix (associated with a quantization conversion table) is determined by a heuristic process 1100 as shown in Figure 11. A quantization matrix for SAR data 202 may be determined by selecting an element of the quantization matrix in step 1103 and perturbing the value of the selected element in step 1105. In step 1105, the selected element is incremented and decremented by incremental values. In step 1107, root means square errors (RSME) are calculated for different compression ratios. The selected value of the selected element is the value corresponding to a minimal root mean square error. If there are more elements in the quantization matrix to be processed, as determined in step 1109, the element indices (i,j) are incremented in step 1111, and the next element is selected in step 1103. Steps 1105 and 1107 are repeated for the next element. The calculation of the quantization matrix is completed after all the elements are processed.
- [55] In another variation of the embodiment, the quantization matrix is determined by the statistical characteristics of the DCT matrix, as was previously discussed. The quantization matrix is subsequently modified according to heuristic process 1100.
- [56] Transformed data 206 are quantized according to corresponding transform statistics that are associated with the DCT coefficients. DCT coefficients can be represented as departures from a standard statistical distribution function (e.g., Laplacian, Gaussian, or Rayleigh). (A Laplacian function has a form of  $e^{-|x|}$ , while a Gaussian function has a form of  $e^{-x^2}$ .) Figure 9 shows a representative histogram for a low order Discrete Cosine

Transform (DCT) coefficient, DCT coefficient (1,1), in accordance with an embodiment of the invention. A number of observations 901 is shown in relation to corresponding bin values 903. Actual data 905 is shown along with a Laplacian relation 907 and a Gaussian relation 909. Also, Figure 10 shows a representative histogram for a high order Discrete Cosine Transform (DCT) coefficient, DCT coefficient (7,7), in accordance with an embodiment of the invention. A number of observations 1001 is shown in relation to corresponding bin values 1003. Actual data 1005 is shown along with a Laplacian relation 1007 and a Gaussian relation 1009. Analysis of the exemplary SAR data reveals a relationship with respect to the low order and high order DCT coefficients. By plotting the Laplacian and Gaussian functions and comparing the corresponding values with the DCT coefficient data of the exemplary SAR data, it is determined that low order terms can be better represented by the Laplacian function, and the higher order terms can be better represented by the Gaussian function for typical SAR data. Quantization by quantizer 205 is designed by accounting for the complex SAR image DCT statistics as exemplified by Figures 9 and 10. As the probability distribution becomes more focused about a zero value for a DCT coefficient, the less is the relative significance of the DCT coefficient with respect to other DCT coefficients. Consequently, the corresponding entry in the quantization conversion table may be greater for the DCT coefficient.

- [57] Other embodiments of the invention may utilize other transform types such as a Discrete Fourier Transform (DFT) or a discrete z-transform, both transforms being well known in the art. However, with a selection of a different transform, the transform statistics may be different as reflected by the design of quantizer 205.
- [58] Quantized SAR data 208 are consequently processed by encoder 207 (e.g. a Huffman encoder). Each output 210 (comprising a compressed I component and a compressed Q component) of encoder 207 comprises an encoder pair (comprising a number of zeros that precede output 210 and a number of bits that represent a value of the corresponding DCT coefficient) and the value of the corresponding DCT coefficient (SAR data 208). Encoder 207 may provide additional compression by removing a degree of redundancy that is associated with the encoder pair and SAR data 208 (in which frequently occurring





apparatus 200 may achieve near-lossless results for magnitude images and minimal degradation to phase information.

### **Detailed Description of the Invention (Second-Generation Embodiments)**

#### **Processing Interleaved Components**

- [65] Figure 13 shows an architecture 1300 for processing synthetic aperture radar data 202 in which components are split in accordance with an embodiment of the invention. Data 202 comprises a received I component and a received Q component that are interleaved. Figure 14 shows a data stream 1400 that transports complex SAR data 202. Data stream 1400 interleaves received I component samples (samples 1401, 1405, 1409, and 1413) with corresponding received Q component samples (samples 1403, 1407, 1411, and 1415).
- [66] Referring to Figure 3, as previously discussed, adaptive source data calculations module 301 splits (separates) the received I component from the received Q component before further processing SAR data 202. With architecture 1300, the splitting of I and Q components is functionally associated with module 403 (as shown in Figure 4A). As shown in architecture 1300, the I component and the Q component are separately processed for compressing and decompressing SAR data 202.
- [67] Figure 15 shows splitting data stream 1400 into I component 1551 and Q component 1553. I component 1551 comprises I component samples 1501, 1503, 1505, and 1507, and Q component 1553 comprises Q component samples 1509, 1511, 1513, and 1515.
- [68] Referring to Figure 13, modules 1301 and 1303 process (compress and decompress) the I component, and modules 1305 and 1307 process the Q component. In the embodiment, I component data and Q component data are transferred by modules 1302 and 1306, respectively. (As examples, data may be transferred through file transfers, data tape transfers or radio transmission transfers.) The processed data is rendered by module 1309. Architecture 1300 is incorporated into the apparatus as previously discussed in Figure 3.



- [69] Figure 16 illustrates a second architecture 1600 for processing synthetic aperture data 202 in which components are interleaved in accordance with an embodiment of the invention. With architecture 1600, interleaved I and Q component samples (for example as shown in Figure 14) are processed by compress interleaved data module 1601 and decompress interleaved data module 1603. In the embodiment, interleaved data are transferred by module 1602. (As examples, interleaved data may be transferred through file transfers, data tape transfers or radio transmission transfers.) After processing by modules 1601 and 1603, I data 1607 is split from Q data 1609 by module 1605. Processed data (data 1607 and data 1609) is rendered by module 1611.
- [70] In the embodiment, modules 1601 and 1603 processes interleaved data, where the I component and the Q component have approximately the same statistical characteristics. Typically, the resulting compression ratio decreases the more that the statistical characteristics of the I component differ from those of the Q component.

#### **Determination of Data Type**

- [71] Figure 17 shows an apparatus 1700 that is a variation of apparatus 800 as shown in Figure 8. As shown in Figure 17, preprocessor 1701 corresponds to preprocessor 801, transform module 1703 corresponds to module 203, modified quantizer module 1705 corresponds to quantizer 205, encoder module 1707 corresponds to encoder 207, knowledge base 1711 corresponds to knowledge base 807, interface 1713 corresponds to interface 811, and adaptive control loop 1751 corresponds to adaptive control loop 251 in relation to Figure 8. Apparatus 1700 also includes training mode feedback 1753 and metadata output 1755, which will be discussed.
- [72] As with adaptive control loop 251 as shown in Figure 8, preprocessor 201 (as shown in Figure 17) provides identification information about the data type for SAR data 202 to modified quantizer module 1705 through adaptive control loop 1751. In the embodiment, preprocessor 201 provides metadata, e.g., mean, standard deviation, maximum data value, and minimum data value, from which modified quantizer module 1705 can identify the data type and retrieve the appropriate quantization conversion table from knowledge base 1711.



- [78] In step 1811, the maximum value and the minimum value of SAR data 202 are determined. Furthermore, the mean and the standard deviation of SAR data 202 are calculated in step 1813. The metadata (comprising the minimum value, the maximum data, the mean, and the standard deviation) are compared to corresponding metadata of known data types in step 1815. In step 1817, if the data type is known, the data type is identified in step 1821. Otherwise, the data type is assumed to be the default data type in step 1819.
- [79] As can be appreciated by one skilled in the art, a computer system with an associated computer-readable medium containing instructions for controlling the computer system can be utilized to implement the exemplary embodiments that are disclosed herein. The computer system may include at least one computer such as a microprocessor, digital signal processor, and associated peripheral electronic circuitry.

**We Claim:**

1. A method for compressing received data comprising a first received component and a second received component, the method comprising:

(a) receiving an interleaved stream of a first plurality of first received component samples with a second plurality of second received component samples;

(b) converting the first received component to a first converted component in accordance with a statistical characteristic; and

(c) converting the second received component to a second converted component in accordance with the statistical characteristic, wherein a resolution of at least one of the converted components is reduced with respect to a corresponding received component.

2. The method of claim 1, further comprising:

(d) determining the statistical characteristic that is associated with the first received component and the second received component.

3. The method of claim 1, wherein (b) comprises mapping the first received component to a plurality of bins in accordance with the statistical characteristic in order to form the first converted component and (c) comprises mapping the second received component to the plurality of bins in accordance with the statistical characteristic in order to form the second converted component.

4. The method of claim 1, further comprising:
- (d) transforming the first converted component into a first transformed component and the second converted component into a second transformed component, wherein a first transformed plurality of first transformed component samples is interleaved with a second transformed plurality of second transformed component samples;
  - (e) interleaving a first transformed plurality of first transformed component samples with a second transformed plurality of second transformed component samples;
  - (f) quantizing the first transformed component into a first quantized transform and the second transformed component into a second quantized transform; and
  - (g) interleaving a first quantized plurality of first quantized transform samples with a second quantized plurality of second quantized transform samples.
5. The method of claim 4, further comprising:
- (h) encoding the first quantized transform into a first compressed component and the second quantized transform into a second compressed component; and
  - (i) interleaving a first compressed plurality of first compressed component samples with a second compressed plurality of second compressed component samples.
6. The method of claim 1, wherein the first received component corresponds to a received In-phase (I) component and the second received component corresponds to a received Quadrature (Q) component.
7. A computer-readable medium having computer executable instructions for performing the steps recited in claim 1.





16. The method of claim 11, wherein (a) comprises:
- (i) obtaining a first quantized transform and a second quantized transform;
  - (ii) inverse quantizing the first quantized transform into a first transformed component and the second quantized transform into a second transformed component; and
  - (iii) inverse transforming the first transformed component into the first converted component and the second transformed component into the second converted component.
17. The method of claim 16, wherein (i) comprises:
- (1) obtaining a first compressed component and a second compressed component; and
  - (2) decoding the first compressed component into the first quantized transform and the second compressed component into the second quantized transform.
18. A computer-readable medium having computer-executable instructions for performing the steps recited in claim 11.
19. A computer-readable medium having computer-executable instructions for performing the steps recited in claim 12.
20. An apparatus for decompressing data, the apparatus comprising:
- a decompression module that obtains a first compressed component and a second compressed component, that converts the first compressed component to a first decompressed component and the second compressed component to a second decompressed component in accordance with a statistical characteristic of the data, and that interleaves a first plurality of first compressed component samples with a second plurality of second compressed component samples; and
  - a component separation module that splits the first decompressed component from the second decompressed component.



21. A method for quantizing a transformed first component and a transformed second component, the method comprising:

(a) selecting a quantization conversion table according to a data type associated with received data; and

(b) modifying the first transformed component into a first quantized transform and the second transformed component into a second quantized transform according to a corresponding entry of the quantization conversion table.

22. The method of claim 21, wherein (a) comprises:

(i) if the received data includes header information, parsing the header information to obtain the data type; and

(ii) if the received data does not include the header information, analyzing the received data to deduce metadata and utilizing the metadata to determine the data type.

23. The method of claim 22, wherein (ii) further comprises:

(1) if the metadata is not associated with a known data type, identifying the data type as a default data type.

24. The method of claim 22, wherein the metadata is selected from the group consisting of a mean, a standard deviation, a maximum value, and a minimum value of the received data.





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## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
Y	1-20	WO 2004/004309 A2 (SCIENCE APPLICATIONS) see the whole document
Y	1-20	US 2004/0021600 A1 (WITTENBERG) e.g. para. 0005
Y	1-20	US 5546085 A (GARNAAT et al) e.g. col.4, ll.37-48

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### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>X</sup> :

Worldwide search of patent documents classified in the following areas of the IPC<sup>07</sup>

G01S; H03M

The following online and other databases have been used in the preparation of this search report

Online: WPL, EPODOC, INSPEC